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Purchase and Utilization of New Fuel Efficient Vehicles in the US: Evidence from the 2009 National Household Transportation Survey Data

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ABSTRACT: This paper applies a simultaneous equation model to examine the relationship between choices of new fuel efficient vehicles and their utilization using the 2009 NHTS data. The regression results indicate that travelers purchasing new fuel efficient vehicles with a fuel economy of at least 30 mpg drive more on a monthly basis than others owning a new vehicle with lower fuel economy. In addition, those who travel more are more likely to purchase a new fuel efficient vehicle with a fuel economy of at least 30 mpg in the study period. The gasoline price has a significant negative impact on new vehicle utilization while a significant positive impact on choices of new vehicles with a fuel economy of at least 30 mpg.

Keywords: new fuel efficient vehicle; new vehicle utilization; simultaneous equation model; impact of gasoline prices; vehicle type choice
JEL Classifications: R22; R41

1. Introduction

According to the Federal Highway Administration, more than 3.03 trillion vehicle miles were traveled on U.S. roads and highways and around 176,100 million gallons of gasoline were used in 2007. Although people faced historically high fuel prices and economic downturn in 2008, the total vehicle miles traveled (VMT) in the United States declined by around 1.8 percent (Federal Highway Administration, 2010). After another 0.5 percent decline in 2009, the VMT in 2010 started to increase again.

The persistent high travel demand and gasoline consumption is of particular interest because of various concerns ranging from national energy security to environmental pollution. It was estimated that vehicles used for transportation in the US released 1.6 billion metric tons of greenhouse gases into atmosphere each year (US Department of Energy, 2012). Reducing greenhouse gas emissions from transportation have to be through either improving fuel efficiency or reducing travel demand (or ideally a combination of both). For the existing stock of vehicles in service, reducing greenhouse gas emissions could be achieved by driving less. For new vehicles, reducing greenhouse gas emissions could be achieved if more people decide to purchase fuel efficient vehicles. For example, if a consumer decides to buy a new vehicle with a fuel economy of 25 mpg instead of 20 mpg, around 17 tons of greenhouse gas emissions over the lifetime of the vehicle could be reduced (US Department of Energy, 2012).

During the past few years, Corporate Average Fuel Economy (CAFE) standards have been strengthened to reduce greenhouse gas emissions and fuel consumption. In August 2012, President Obama announced a new regulation to increase fuel economy to the equivalent of 54.5 mpg for cars and light-duty trucks by model year 2025, a further (and a significant) increase from the 2012-2016 CAFE standards. As a response, automobile producers have been in the process of making significant changes to meet the standards and fuel economy of new vehicles has been improving consistently. The average fuel economy of new passenger cars has increased from 31.5 mpg in 2008 to 33.8 mpg in 2011. The average fuel economy of new light trucks weighted less than 8,500 lbs has improved from 22.5 to 24.2 mpg (US Bureau of Transportation Statistics, 2012) in the same period.

The market share of fuel efficient vehicles, however, seems to lag behind. As shown in Table 1 which presents the market share of passenger cars and light truck in terms of fuel economy, the market share of those passenger cars at the higher end of fuel economy distribution was quite low. For example, new vehicles with a fuel economy of at least 35 mpg accounted for 3, 2.2, and 5 percent in 2008, 2009, and 2010 respectively. The market shares of light trucks with a fuel economy of at least 25 mpg showed no difference: 1.4, 1.9, and 3.2 percent in 2008, 2009 and 2010 respectively.

Table 1. Market Share of New Vehicles by Fuel Economy

Market Share of Passenger Cars by Fuel Economy (mpg)								
Model Year	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
2008	0.3%	8.9%	44.6%	33.3%	9.9%	0.3%	0.4%	2.3%
2009	0.2%	5.1%	33.7%	40.7%	18.1%	0.4%	0.3%	1.5%
2010	0.2%	6.1%	31.1%	37.4%	20.2%	1.0%	1.2%	2.8%
Market Share of Light Trucks by Fuel Economy (mpg)								
2008	8.3%	65.1%	25.1%	1.1%	0.3%			
2009	2.2%	57.9%	37.9%	1.6%	0.3%			
2010	3.3%	58.5%	35.0%	3.0%	0.2%			

Source: U.S. Environmental Protection Agency, Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2010, Appendix C.

Motivated by the market results, this paper examines the determinants of choices of new fuel efficient vehicles and new vehicle utilization using the 2009 National Household Travel Survey (NHTS) data. This paper has three issues to examine. It is generally expected that travelers who drive more miles are more likely to purchase a fuel efficient vehicle and those who owning fuel efficient vehicles are more likely to drive more. The first issue, thus, is to test whether there is a positive association between selection of new fuel efficient vehicles and their utilization.

The second issue is to identify the impact of gasoline price on new vehicle utilization and in particular choices of new fuel efficient vehicles. Most of earlier studies on this issue are based on micro data in the periods of 1990s and early 2000s when gasoline prices were low and relatively stable. While fuel prices started to rise consistently from 2004, the situation was dramatically changed due to the escalation of oil prices in 2008. A natural question, therefore, is how and to what extent the significant change of gasoline prices affects new fuel efficient vehicle purchase and vehicle utilization. Given the expected volatile gasoline prices down the road, the findings based on 2008-2009 data may shed light on forecasting travelers' behavior change in the future.

This paper focuses on fuel efficient vehicles because fuel economy is the only factor[1] that really matters from the perspective of energy consumption and emissions. In this paper, a fuel efficient vehicle[2] is defined as whether a vehicle achieves a fuel economy of at least 30 mpg. This cut-off point is selected because as shown in Table 1 and figure 1 (based on the sample of this study), this figure is at the top 25 percent of fuel economy distribution.

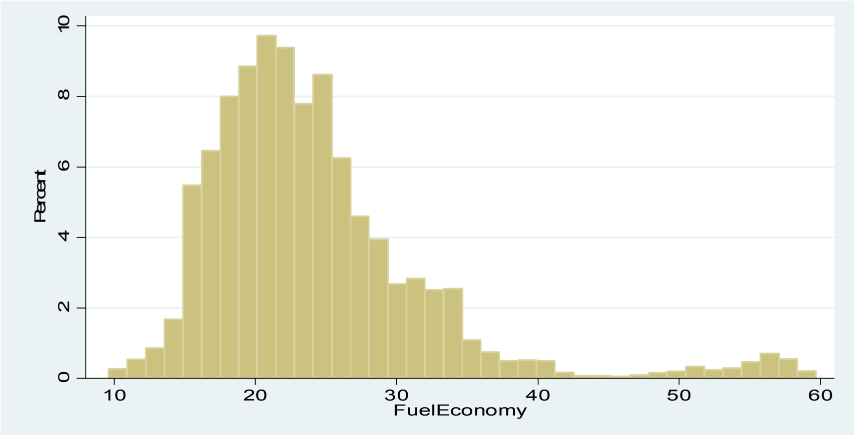
When analyzing the association between new vehicle utilization and fuel economy of vehicle, there is one important empirical issue to address. Since some factors that are either unobserved or uncontrolled for can affect whether a new fuel efficient vehicle is purchased and/or how the new fuel efficient vehicle is used, both variables are endogenous. For new vehicles, the purchase and utilization could be jointly determined. This is the major reason why this paper focuses on the new vehicles. In

[1] There is no doubt that consumers use different criteria to select their new vehicle. Factors that may be considered include (but not limited to): household needs and preference, vehicle performance, amenities, space, safety, fuel economy, style, storage, etc. For consumers in the new vehicle market, fuel economy may be one of the many factors to consider. From the perspectives of energy consumption and emissions, however, fuel economy is the one that really matters.

[2] Although fuel economy is intrinsically a continuous variable, our focus is to examine who are purchasing new fuel efficient vehicles with fuel economy at the higher end of the distribution in the market, how they use their new fuel efficient vehicles, and what is the impact of gasoline prices on these two variables. The categorization of vehicle fuel economy better serve the purposes of this paper. Nevertheless, an exercise was made using the continuous fuel economy and the major findings of this paper remain unchanged.

this paper, a simultaneous equation model with one dichotomous choice equation and one continuous vehicle utilization equation is applied to address this issue. The findings from this paper may represent an important contribution toward understanding how traveler's new vehicle choice in terms of fuel economy and utilization decisions respond to a wide variety of factors. This may help identify other supplementary policy tools to further reduce vehicle emissions in addition to tougher CAFE standards.

Figure 1. The Distribution of Fuel Economy of Vehicles



2. Literature Review

There is a growing literature analyzing and modeling vehicle type choices and utilization. Earlier studies focus on consumers' choices on the number of vehicles owned with or without vehicle utilization decisions (Mannering and Winston, 1985; Train, 1980, 1986; Bhat and Purugurta, 1998; Dargay and Vythoulkas, 1999; Hanley and Dargay, 2000). Given the rising fuel prices and concerns of environmental impact of travel demand, researchers in recent years have shifted their focus on understanding the association between vehicle utilization and number of vehicles by type (West 2004, Feng et al., 2005; Bhat et al. 2009; Spissu et al., 2009; Kitamura et al., 2000; Choo and Mukhtarian, 2004) and fuel efficiency (Turrentine and Kurani 2007).

Many factors have been identified to affect household vehicle choice. Lave and Train (1979) find that household demographic and economic characteristics are important determinants of household vehicle choices, which is confirmed later by other empirical analyses (Golob et al. 1997, Mannering and Winston, 1985; Bhat and Purugurta, 1998). In addition, vehicle choices are also affected by travel cost. Gallagher and Muehlegger find that hybrid vehicle sales are higher in those states with higher fuel costs or public policies available to provide incentive for consumers to purchase hybrid vehicles.

There is a vast body of literature examining the relationship between vehicle utilization and built environment while controlling for demographic and economic characteristics (Bento et al. 2006, Bhat and Guo, 2007; Small and Van Dender, 2007; Frank and Pivo, 1994; Cervero, 1994; Schimek, 1996; Holtzclaw et al., 2002; Zhang, 2004; Ewing et al., 2007; Feng et al., 2005; Brownstone and Golob, 2009; Bhat et al., 2009; Fang, 2008). There is no consensus on the impact of population density on VMT although many empirical works support the hypothesis that road network has a positive impact on VMT (Frank and Pivo, 1994; Cervero, 1994; Schimek, 1996; Bento et al., 2006; Su, 2010, 2011).

Some scholars are interested in choices of fuel efficient vehicles. Turrentine and Kurani (2007) find that fuel economy for households is not only about private cost saving, it can also be symbolic. Based on their survey results, they also find that consumers don't analyze their fuel cost in a systematic way in the vehicle purchase and fuel consumption process. Their results suggest that consumers respond to fuel economy technology and fluctuations of gasoline prices in a more complex way than the rationality assumption suggests.

Most articles examining only vehicle holdings or type use standard discrete choice models (e.g. multinomial logit (MNL, nested logit, and mixed logit). For vehicle utilization, the most commonly used method is linear regression for one-year cross sectional data and fixed effect model for panel data. For the joint determinants of vehicle holdings or types and vehicle utilization, most studies use a combined model of discrete–continuous specifications of vehicle ownership (discrete) and utilization (continuous) choices. Typically, the jointness is analyzed by capturing the correlation between unobserved factors that impact both the choice of vehicle type and vehicle utilization. Many of these studies use or modify the method developed by Dubin and McFadden (1984). For example, while applying the sequential estimation techniques proposed by Dubin and McFadden, West (2004) utilizes the conditional expectation correction terms while some others (Mannering and Winston, 1985; Train, 1986; Goldberg, 1998) use instrumental variables.

Bhat and Sen (2006) develop the multiple discrete-continuous extreme value (MDCEV) models to tackle the issue that households own and use multiple vehicles. Based on this method, Bhat et al. (2009) apply a joint nested MDCEV-MNL model to examine the determinants of households' vehicle holdings and travel demand. Instead of imposing restrictive distribution assumptions on the dependency structures between the errors in the discrete choice of vehicle type and continuous vehicle utilization, Spissu et al. (2009) apply a copula-based methodology to facilitate estimation. These two papers focus on different methodology but apply the same data from the 2000 San Francisco Travel Survey.

Similar to many earlier studies, this paper uses a simultaneous equation model to jointly estimate vehicle choices in terms of fuel economy and vehicle utilization. The paper, however, focus on whether a consumer purchase a new fuel efficient vehicle and how the new fuel efficient vehicle is utilized using the 2009 NHTS survey data. This most recent national dataset enables us to identify the determinants on a broader geographic basis, which may avoid the potential bias from a sample of one region. Differing from the earlier studies using data from 1990s and early 2000 when gasoline prices were relatively low and stable, this new dataset allows us to investigate whether there is any difference in the impact of gasoline prices on new vehicle type choices and utilization.

3. Data and Variables

The major source of the data used in this paper is the 2009 National Household Travel Survey (NHTS) conducted by the Federal Highway Administration. The 2009 National Household Travel Survey is the most recent comprehensive household survey of both daily and long-distance travel occurring between March 2008 and April 2009. The dataset contains four separate files that report travel-related characteristics of households and household members in the United States. The vehicle file contains information on the types of fuels, annual cost of fuel purchase, fuel price, vehicle characteristics, vehicle miles traveled, whether the vehicle has a main driver, and other related household demographics. Only the new vehicles (2008 and 2009 model with a main driver and purchased within 12 months from the survey date) are selected as the base sample. Then the vehicle information is combined with the household and person files to add more information on the household member's income, education, and occupation.

Dependent Variables

There are two dependent variables. The first one is the average monthly VMT, derived by dividing the total miles traveled by the number of months of owning the vehicle. Since our interest focuses on recently purchased new vehicles in the survey period, some travelers only owned their vehicles for a few months. Average monthly VMT is therefore a more comparable measure of vehicle utilization than annual VMT. This and all other continuous variables in is paper are in natural log form. The second dependent variable is a binary variable indicating whether the vehicle is a fuel efficient vehicle. The cutoff point for fuel efficient vehicle is 30 mpg. Other cut-off points of 31, 32 (one standard deviation above the mean fuel economy of our sample) are also used to avoid the impact of arbitrariness.

Fuel price is captured by the gasoline price per gallon. The 2009 NHTS did not collect vehicle fuel prices via the fuel price diary (U.S. Bureau of Transportation Statistics, 2010). Instead, its value was assigned based on weekly regional gasoline price during which the household was surveyed (US Federal Highway Administration, 2009). This measure, therefore, may not accurately capture the overall fuel cost in the sample period when gasoline prices fluctuated in a wide range. To reduce the potential bias, one alternative is to use the state average gasoline price in 2008 (although not ideal, the restriction is from the fact that for many observations, the only location identifier is state). The data are from the Bureau of Transportation Statistics[3].

Other explanatory variables are categorized into two groups to capture the impact of household demographic and economic characteristics as well as area spatial characteristics.

Household Demographic and Economic Characteristics

Following most previous studies, we control for demographic and economic characteristics. The variables in this group include household lifecycle, household income, and main driver's education level, race, and occupation.

Household lifecycle indicates household structure in terms of the number of adults and the number of children. Based on the household lifecycle categories from the NHTS' household file, nine dummy variables are created to reflect inter-household structure differences. The variables include single; two-adult households without children; single-parent households with child or children aged below 5, 16, and 21, respectively; and two-parent households with child or children aged below 5, 16, and 21, respectively; and seniors. Households with more children and more than 2 adults may have different vehicle choices and utilization. Two more variables are created to capture this impact: three-or-more-adult household and three-or-more-children household[4].

Data on household income, which refers to the previous year's combined household income before tax, are reported in 18 ranges. The midpoint of each interval is used. For the highest income category, median income of the 90th percentile (approximately $118,200 in 2008) is used (US Bureau of Census, 2009). Considering that household income may be positively related to household size, an alternative is to derive income per capita. The natural log of income per capita is used in the regression for robustness check and the major findings of this paper remain unchanged.

Since all the vehicles in our sample have a main driver, we are able to control for the main driver's education level, occupation, and race. Three dummy variables of education level are created: associate degree, bachelor's degree, graduate degree. The base category is high school or below. For categories of occupation are reported by 2009 NHTS: sales/service, administrative support, manufacture/construction/maintenance/farming, professional/managerial. Considering the potential correlation between occupation and education level, only sales/service and manufacture/construction/-maintenance/farming are included as dummy variables. Two other dummy variables are used to reflect whether the main driver has more than one job or is allowed to work on flexible schedules. Three dummy variables have been created to reflect his/her race: white, African-American, and Asian[5]. The base is the other[6].

Area Characteristics

The second group of control variables is the spatial characteristics of the area in which the household resides. The important factors identified by the literature include the distribution of population and employment with the area, the road network, public transportation availability and services, and traffic congestion. Our selection of variables, however, is restricted by data availability. For many travelers surveyed by the 2009 NHTS, their geographic identifiers were suppressed for confidentiality. This makes it impossible for us to obtain measures of certain spatial characteristics including employment density, congestion level, and road network density.

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[3] Another alternative is to use the average monthly gasoline price for the survey period covered. The data are from EIA and the major findings of this paper remain unchanged.

[4] The dummy variable three-or-more children household is included in the initial model specification and its coefficients are never statistically significant. It is therefore dropped for the model specification reported in Tables 3 and 4.

[5] Various combinations of interactive variables have also been experimented to distinguish specific groups of travelers' vehicle choice and utilization. For example, 72 dummy variables based on the combination of race, education and household structure are experimented in the regression. Given the majority of observations are white in this sample, only a few has significant coefficients. Recognizing this sample may not well capture the diversity of new vehicle purchasers in the survey period, this is the only sample we can get at the individual level. Results from this study may still shed some light on the determinants of households' choices of new fuel efficient vehicles and how they use those new vehicles in the time of high fuel cost.

[6] According to the 2009 NHTS, the other includes "American Indian, Alaskan Native, Native Hawaiian, other Pacific Islander, Hispanic/Mexican Only, White & African American and other specify."

The NHTS reports population density at the block and tract level. They are categorized into 8 groups with density values of 50, 300, 750, 1500, 3000, 7000, 17,000, and 30,000, respectively. We created five dummy variables to reflect the population density at the household's block level with the base of density value of at least 7,000 persons per square mile. A dummy variable indicating whether rail service is available in the area where the household resides is also included to capture the impact of rail. Another dummy variable is created to capture the impact of rural areas. The summary of statistics is reported in Table 2.

Table 2. Summary of Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
Monthly VMT	1,307.66	887.70	100	5,999
Household Income	81,771.67	34,216.55	2,500	118,200
Average Gasoline Price	3.46	.164	3.21	3.84

Dummy Variables

Variable	Frequency
Single	5.06%
Two-Adult w/o Children	27.1%
One-Adult w/ Child or children Under 5	0.11%
Two-Adult w/ Child or children Under 5	10.5%
One-Adult w/ Child or children Under 16	0.76%
Two-Adult w/ Child or children Under 16	15.7%
One-Adult w/ Child or children Under 21	0.42%
Two-Adult w/ Child or children Under 21	6.96%
Senior	5.31%
Three-or-more Adult Household	16.38%
Population Density below 50 per Square Mile	11.88%
Population Density below 300 per Square Mile	17.63%
Population Density below 750 per Square Mile	11.61%
Population Density below 1500 per Square Mile	15.01%
Population Density below 3000 per Square Mile	21.41%
Multiple Jobs	5.84%
Flexible Work Schedule	26.53%
Sales/Service	22.14%
Manufacture/Construction/Maintenance/Farming	37.49%
Associate	27.75%
Bachelor	28.46%
Graduate	20.98%
N	7087

4. Simultaneous Equation Model

The empirical specification is based on a model that jointly determines choice of new fuel efficient vehicles and their utilization in terms of monthly VMT. Travelers are assumed to maximize their utility by selecting the new vehicles that best meet the needs based on their preference and expected utilization. Recognizing that vehicle choice is multi-dimensional, this paper focuses on the fuel economy given its relevance from the perspective of energy consumption and environmental concerns.

It is generally agreed that the estimation of an econometric model proves association, not causation. One advantage of a structural model, however, is that this structural specification makes it clear what is the direction by which those associations occur. This may help researchers and readers to make more informed judgment whether causality can be assumed. In this paper, we are interested in whether a joint relationship between choice of new fuel efficient vehicle with a fuel economy of at least 30 mpg and vehicle utilization exists. VMT is a continuous variable whereas whether purchase a fuel efficiency vehicle is a dichotomous variable. Appropriate estimation methods for such models has been introduced in Heckman (1978), Amemiya (1978), Maddala (1983), but Keshk (2003) is the first to develop a program using two-stage probit least squares estimation method to fit such models. This structural model based on Keshk (2003) is discussed below.

Empirical Implementation

As discussed above, the system is composed of two equations. The first one is the new vehicle utilization equation with natural log of monthly VMT as dependent continuous variable. The right-side variables for this equation include another endogenous variable (a dummy variable indicating whether the traveler is driving a new vehicle with a fuel economy of at least 30 mpg) and a matrix of exogenous variables denoted as X_1. The second equation is the discrete choice equation with a dichotomous dependent variable indicating whether a traveler purchased a new fuel efficient vehicle. The right-side variables for this equation include the endogenous vehicle utilization variable and a matrix of exogenous variables denoted as X_2. For identification purpose, X_1 and X_2 share a group of common variables while also include equation-specific variables.

The system of equations is formulated as follows:

$$VMT^* = \gamma_1 FuelEfficientVehicle^* + \beta_1^{'} X_1 + \varepsilon_1 \quad (1)$$

$$FuelEfficientVehicle^* = \gamma_2 VMT^* + \beta_2^{'} X_2 + \varepsilon_2 \quad (2)$$

where VMT^* is directly observed, $FuelEfficientVehicle$ is dichotomous endogenous variable and is observed as 1 (fuel efficient vehicle purchased) if $FuelEfficientVehicle^*$ (the underlining utility maximization that is not directly revealed) > 0; otherwise, its value is zero (that is, fuel efficient vehicle is not purchased). γ_1 and γ_2 are the parameters of the endogenous variables in equation 1 and 2 respectively and expected not to equal zero; X_1 and X_2 are matrices of exogenous variables used in equation 1 and 2 respectively; ε_1 and ε_2 are error terms that are assumed to be contemporaneously correlated with $\sigma^2{}_1, \sigma^2{}_2$ and σ_{12} as their variances and covariance respectively.

Given the underlying process of utility maximization is not directly observed and $FuelEfficientVehicle$ has value of either 1 or 0, the equations (1) and (2) can be rewritten as:

$$VMT = \gamma_1 \sigma_2 (FuelEfficientVehicle^{**}) + \beta_1^{'} X_1 + \varepsilon_1 \quad (3)$$

$$FuelEfficientVehicle^{**} = (\gamma_2 / \sigma_2) VMT + (\beta_2^{'} / \sigma_2) X_2 + \varepsilon_2 / \sigma_2 \quad (4)$$

The estimation then follows a typical two-stage procedure. In the first stage, the following two equations are measured based on all the exogenous variables (included in X_1 and X_2) in (3) and (4) denoted as X below.

$$VMT = \Pi_1^{'} X + v_1 \quad (5)$$

$$FuelEfficientVehicle^{**} = \Pi_2^{'} X + v_2 \quad (6)$$

where $\Pi_1^{'}$ and $\Pi_2^{'}$ are vectors of parameters to be estimated, v_1 and v_2 are vectors of error terms. $\Pi_1^{'}$ and $\Pi_2^{'}$ can be obtained by estimating (5) via OLS while estimating (6) via probit. From the reduced-form estimates, the predicted values for each equation are obtained to use in the second stage of estimation. In the second stage, the original endogenous variables in (3) and (4) are replaced by their predicted values from the first stage. The following two equations are fitted:

$$VMT = \gamma_1 \widehat{FuelEfficientVehicle^{**}} + \beta_1 X_1 + \varepsilon_1 \quad (7)$$

$$FuelEfficientVehicle^{**} = \gamma_2 \widehat{VMT} + \beta_2 X_2 + \varepsilon_2 \quad (8)$$

Again, (7) is estimated using OLS and (8) is via probit. The final step is the correction of the standard errors based on the variance-covariance matrices of (7) and (8) (for detailed matrices information, see Keshk (2003), pp.160).

5. Regression Results

The simultaneous equation model with 7087 observations is estimated using the Stata (command cdsimeq). The second stage regression results with corrected standard errors for the monthly VMT are reported in Table 3. The probit regression results for choices of new fuel efficient vehicles are reported in Table 4.

Table 3. New Vehicle Utilization Equation

Variable	VMT	VMT	VMT
Driving a vehicle with a fuel economy of at least 30 mpg	.648*** (4.43)		
Driving a vehicle with a fuel economy of at least 31 mpg		.707*** (4.28)	
Driving a vehicle with a fuel economy of at least 32 mpg			.793*** (4.11)
ln(StateGas)	-1.434*** (4.23)	-1.335*** (3.86)	-1.397*** (3.68)
ln(Income)	.268*** (5.66)	.284*** (5.41)	.301*** (5.11)
White	.004 (.07)	-.005 (.07)	-.004 (.05)
African-American	.076 (.73)	.054 (.49)	.077 (.64)
Asian	-.368*** (3.20)	-.378*** (3.09)	-.384*** (2.89)
Single	-.202*** (3.10)	-.195*** (2.84)	-.207*** (2.74)
Two-Adult w/o Children	-.078** (2.06)	-.080** (2.00)	-.079* (1.82)
One-Adult w/ Child/Children Under 5	-.522 (1.35)	-.597 (1.45)	-.699 (1.54)
Two-Adult w/ Child/Children Under 5	.154*** (3.37)	.181*** (3.59)	.207*** (3.62)
One-Adult w/ Child/Children Under 16	.034 (.23)	.013 (.08)	-.051 (.29)
One-Adult w/ Child/Children Under 21	-.071 (.36)	-.066 (.32)	-.127 (.56)
Two-Adult w/ Child/Children under 21	-.062 (.99)	-.092 (1.33)	-.112 (1.46)
Senior	-.182*** (2.98)	-.178*** (2.74)	-.178** (2.51)
Three-or-More-Adult Households	-.158*** (2.79)	-.139** (2.47)	-.163** (2.55)
Population Density below 50 per Square Mile	.520*** (8.74)	.555*** (8.15)	.558*** (7.61)
Population Density below 300 per Square Mile	.350*** (7.29)	.358*** (6.92)	.349*** (6.39)
Population Density below 750 per Square Mile	.275*** (5.28)	.288*** (5.08)	.292*** (4.74)
Population Density below 1500 per Square Mile	.252*** (5.14)	.252*** (4.86)	.253*** (4.51)
Population Density below 3000 per Square Mile	.166*** (3.68)	.159*** (3.39)	.172*** (3.29)
Multiple Jobs	.024 (.43)	.037 (.64)	.045 (.71)
Flexible Work Schedule	.078** (2.43)	.069** (2.03)	.069* (1.86)
Sales/Service	.184*** (4.59)	.192*** (4.59)	.200*** (4.43)
Manufacture/Construction/Maintenance/Farming	.122*** (3.05)	.116*** (2.71)	.111** (2.38)
Associate	-.008 (.21)	-.006 (.16)	-.025 (.56)
Bachelor	.006 (.14)	.001 (.03)	-.018 (.37)
Graduate	-.061	-.063	-.086

	(1.37)	(1.32)	(1.59)
Constant	5.775*** (12.24)	5.541*** (10.68)	5.527*** (9.82)
R^2	.1219	.1222	.1228

Dependent variable is ln (monthly VMT); *** Statistically significant at the level of 0.01, ** at the level of 0.05, * at the level of 0.1; the absolute t value is reported in bracket.

5.1. *Monthly VMT Equation*

One important issue is to examine whether travelers drive more when owing new vehicles with a fuel economy of at least 30 mpg. Regression results indicate that the coefficients of the endogenous variable of owing new fuel efficient vehicles are all positive and statistically significant at the level of at least 0.01. This result indicates that travelers owning new fuel-efficient vehicles with a fuel economy of at least 30 mpg generally drive more than other new vehicle owners.

Another variable of interest is gasoline prices. The coefficients of the gasoline prices from the whole sample are negative and statistically significant at the level of at least 0.001, indicating a strong impact of gasoline price on vehicle utilization in 2008. The coefficients of the gasoline price are -1.43, -1.34, -1.40, for vehicles with a fuel economy of at least 30, 31, 32 mpg respectively. Since both VMT and gasoline prices in natural log form, the results suggest that travelers' VMT fall by 1.34 to 1.43 percent for every one percent increase in gasoline prices. The results obtained here are higher than that obtained by Feng et al. (2005) (ranged from -0.23 to -0.93 depending on vehicle bundle) and most studies based on data in early 2000's and 1990s (Hughes et al., 2006; Bento et al., 2005, Small and Van Dender, 2007). A possible explanation could be that due to the historically high gasoline prices in 2008 and recession in the survey period, many travelers squeeze their travel more than that in other periods when fuel costs also increased.

Among the demographic and economic control variables, income has a positive and statistically significant impact on monthly VMT. The income elasticity ranges from 0.28 to 0.33, which is higher than those obtained by Spissu et al (2009) (0.08-0.15), Small and Van Dender (2007) (0.11), Su (2011) (0.12). A possible explanation may be that given the high gasoline prices, expenditures on gasoline consumption accounted for a much higher percentage of people's disposable income in the survey period than 1990s and early 2000.

As to the other control variables in this category, the regression results indicate that travelers in a 2-adult household with child/children under 5 drive more miles while seniors and those in a household with three or more adults drive less. Drivers working in sales/service drive more miles while Asian-Americans owning such a vehicle drive less.

Area characteristics of the household residence are identified as one of the important factors to affect VMT. Given the data constrain, the variables used to capture the impact of area characteristics are population density dummies. The coefficients of the five dummy variables representing different level of population density are all positive and statistically significant at the level of at least 0.01.The magnitude of the coefficients of these variables declines from the lowest population density of 50 persons per square mile to a population density of around 3000 persons per square mile. This result indicates that compared to those travelers living in the neighborhood with population density of at least 7,000 persons per square mile, the travelers living in lower density areas drive more miles per month. This finding is consistent with many earlier studies (Bento et al., 2005; Small and Van Dender, 2007; Bhat et al., 2009; Su, 2010).

5.2. Probit Fuel-Efficient Vehicle Choice Equation

The question whether consumers take into consideration of future vehicle utilization when they purchase new fuel efficient vehicles can be answered by the coefficients of monthly VMT. They are positive and statistically significant at the level of at least 0.1 for vehicles with fuel economy of at least 30 and 31 mpg. This result suggests when the cut-off points for new fuel efficient vehicles are 30 and 31 mpg, consumers consider their future vehicle usage in their decision to buy a new fuel efficient vehicle. For other higher cut-off points, this positive association still exists but not statistically significant.

What is the impact of gasoline prices on the choices of new fuel efficient vehicles? Regression results indicate that the coefficients of gasoline price are positive and statistically significant at the level of at least 0.001. The coefficients are 1.47, 1.20, and 1.19 for choices of new vehicle fuel economy of at least 30, 31, and 32 mpg respectively. This result indicates that when gasoline prices are higher, people are more likely to purchase new vehicles with a fuel economy of at least 30 mpg. This finding provides evidence to support Spissu et al (2009)'s conclusion that people tend to purchase smaller vehicles when fuel prices are higher (Table 2, pp. 412).

Table 4. Regression Results-Choice of Fuel Efficient Vehicle

Variable	Vehicle with a fuel economy of at least 30 mpg purchased	Vehicle with a fuel economy of at least 31 mpg purchased	Vehicle with a fuel economy of at least 32 mpg purchased
ln(Monthly VMT)	.304*	.288	.238
	(1.66)	(1.65	(1.28)
ln(StateGas)	1.467***	1.201***	1.189***
	(3.81)	(3.10	(3.06)
ln(Income)	-.187***	-.194***	-.190***
	(3.90)	(4.03	(3.94)
White	-.048	-.030	-.027
	(.61)	(.37	(.34)
African-American	.037	.06	.034
	(.29)	(.49	(.26)
Asian	.349***	.335*	.306**
	(2.54)	(2.43	(2.22)
Single	.190**	.167*	.163**
	(2.55)	(2.22	(2.18)
Two-Adult w/o Children	.136***	.129***	.113***
	(3.30)	(3.11	(2.72)
One-Adult w/ Children Under 5	.708	.74	.794*
	(1.52)	(1.61	(1.73)
Two-Adult w/ Children Under 5	-.083	-.115*	-.134**
	(1.31)	(1.80	(2.07)
One-Adult w/ Children Under 16	.216	.22	.288
	(1.16)	(1.22	(1.55)
One-Adult w/ Children Under 21	.289	.25	.309
	(1.21)	(1.08	(1.30)
Two-Adult w/ Children Under 21	.191***	.217***	.220**
	(2.79)	(3.07	(2.12)
Senior	.067	.05	.049
	(.77)	(.67	(.56)
Three-or-More-Adult Household	.289***	.235***	.241***
	(6.18)	(4.99	(5.12)
Population Density below 50 per	-.341***	-.488***	-.356***
Square Mile	(3.56)	(4.05)	(3.69)
Population Density below 300 per	-.227***	-.238***	-.205***
Square Mile	(3.11)	(3.25	(2.79)
Population Density below 750 per	-.208***	-.216***	-.201***
Square Mile	(3.17)	(3.26	(3.03)
Population Density below 1500 per	-.199***	-.186***	-.178***
Square Mile	(3.40)	(3.15	(2.84)
Population Density below 3000 per	-.174***	-.148***	-.150***
Square Mile	(3.48)	(2.96	(2.98)
Rail Availability	.014	.01	.010
	(.30)	(.37	(.20)
Rural	-.027	.00	-.002
	(.53)	(.05)	(.03)
Multiple Jobs	.033	.01	.002
	(.47)	(.15	(.03)
Work Status* Distance to Work	.002*	.002	.002*
	(1.76)	(1.68	(1.71)
Associate	.036	.03	.051
	(.77)	(.67	(1.09)
Bachelor	.078	.081	.099**
	(1.60)	(1.64	(2.00)
Graduate	.130**	.113*	.147**
	(2.52)	(2.17	(2.82)
Annual Income Above 100,000	-.181***	-.166***	-.149***
	(3.66)	(3.35	(2.99)
Constant	-2.171*	-1.727	-1.483
	(1.65)	(1.29	(1.11)
log likelihood	-4369.70	-4267.13	-4193.17
LR Chi^2(28)/Prob> Chi^2	289.02/0.0000	255.27/0.0000	237.71/0.0000

Dependent variable is ln (monthly VMT); *** Statistically significant at the level of 0.01, ** at the level of 0.05, * at the level of 0.1; the absolute t value is reported in bracket.

Among the demographic and economic control variables, household income has a negative impact on choices of new fuel efficient vehicles. The coefficients of household income are negative and statistically significant at the level of at least 0.001. This result indicates that as household income increases, people are less likely to purchase new vehicles with a fuel economy of at least 30 mpg. On the fuel efficient vehicle market in 2008, the prices of 16 out of the 18 vehicle makes with a fuel economy of at least 30 mpg were much lower than the average new vehicle prices. The lower price, combined with the image of small and light vehicles, may be the reason to explain this overall negative impact of income on choices of fuel efficient vehicles. In addition, vehicle is considered as durable goods and when expectation of future economy is not optimistic, many consumers making average income may defer their purchase of new vehicles. Those high income people may therefore, account for a higher percentage of buyers in the vehicle market in the survey period than other years when economic condition is normal. To address this issue, the dummy variable of household income above 100, 000 used and its impact, as predicated, is negative and statistically significant at the level of at least 0.1.

Among other control variables in this category, those in the household structured as 2-adult with child/children younger than 5 are less likely to purchase new vehicles with a fuel economy of at least 31 mpg while 2-adult with child/children younger than 21 and three-or-more-adult households are more likely to make such as purchase. Those consumers with a graduate degree are more likely to purchase a new fuel efficient vehicle.

As to the population density at the neighborhood level, the coefficients of the dummies are all negative and statistically significant at the level of at least 0.01. This result indicates that compared to those living in the neighborhood with population density of 7000 per square mile, others living in lower density areas are less likely to purchase new fuel efficient vehicles.

5.3. Robustness Check

We conduct robustness check to test whether our findings are sensitive to sample selection as well as variable measurement and selection. The first robustness check is conducted to see whether our findings are sensitive to model specification using the same method by Barslund et al. (2007). We divide our variables into two groups. The first group of variables are core variables (including gasoline prices, household income, race (white, black, Asian), household lifecycle variables, education level (associate, bachelor, graduate), occupation (sales/service, manufacturing/construction/maintenance-/farming), multiple job, flexible work schedule, and population density dummy variables (representing 50, 300, 750, 1500, 3000 persons per square mile). These core variables are included in all regressions. The second group contains the test variables (namely, interactive variable of work status and distance to work, dummy variables indicating rural residence, dummy variables indicating that three-or-more-children household, as well as major travel concerns of households: travel cost, congestion, safety). This robustness check is to run regressions including all the core variables and different combinations of testing variables.

Among the 7087 observations in our sample, there are 273 households that purchased two new vehicles and one household purchased three new vehicles in 2008. The error terms for the observations from the same households may be correlated. Our second robustness check is to drop those observations to test whether our major findings are sensitive to this potential problem. The third robustness check is to see whether our findings are sensitive to different measures of gasoline prices (average state gasoline prices from BTS and EIA) and household income (total household income vs. income per capita). The robustness check results indicate that the positive association between purchasing a new fuel efficient vehicle with a fuel economy of at least 30 mpg and vehicle usage remains unchanged. The impact of gasoline prices remains the same with the coefficients range between -1.01 and -1.62 for the monthly VMT equation and 1.17 to 1.52 for the probit vehicle choice equation.

The fourth robustness check is to run regressions on three subsamples: one-vehicle, two-vehicle, and three-or-more-vehicle households. Regression results from the three subsamples reveals that the major findings of this paper remain largely unchanged. The impact of gasoline prices on monthly VMT is negative and statistically significant at the level of at least 0.1 for two-vehicle and three-or-more vehicle households. For one-vehicle households, the coefficients are positive but not statistically significant at the level of 0.1.

While it seems that the results from robustness check are encouraging, it is important to recognize the major limitations of this study. The first limitation of this study is from the measurement of travel cost. The state average gasoline prices may not capture the inter-household differences in their fuel cost accurately. Furthermore, we are unable to capture the time cost of travel, which may also have important impact of travelers' VMT. The second limitation of this study is that amenities of vehicles cannot be captured, which may generate potential bias from omitted variables.

6. Conclusion

This paper applies a simultaneous equation model to examine the relationship between choices of new fuel efficient vehicles and their utilization using the 2009 NHTS data. The regression results indicate that travelers purchasing new fuel efficient vehicles with a fuel economy of at least 30 mpg drive more on a monthly basis than others owning a new vehicle with lower fuel economy9. In addition, those who have higher monthly travel demand are more likely to purchase a new fuel efficient vehicle with a fuel economy of at least 30 mpg in the study period. The gasoline price has a strong negative impact on new vehicle utilization but a strong positive impact on choices of new vehicles with a fuel economy of at least 30 mpg.

This empirical evidence may not be the case in some other countries where many travelers generally drive smaller vehicles compared to those in the US. In those countries, a person who needs to drive much more that the average may like to own a vehicle with lower fuel economy but other amenities that makes travel more comfortable. Our findings may have important implications for policy makers and automobile producers. Given the positive association between the fuel efficient vehicle selection in the new vehicle market and vehicle utilization and the low market share of new vehicles at the higher end of fuel economy in 2008 and 2009, it seems that fuel economy may be an important factor for those with high travel demand. The low market share of new vehicles at the higher end of fuel economy distribution during the period when fuel costs are high suggests that strengthening CAFE standards for all vehicles on the market may better achieve the policy goals of reducing fuel consumption and greenhouse gas emissions.

The significant negative impact of gasoline prices on new vehicle utilization and positive impact on choices of new fuel efficient vehicles suggests that policy tools to increase the variable cost of travel may help further reduce VMT and gradually change the stock of vehicles to be more fuel efficient. In addition, given the overall negative constant terms in the new fuel efficient vehicle choice equation, it is necessary to have joint efforts from both automobile producers and government to inform and educate the public about the greenhouse gas emission of each type of vehicle. To better serve the purpose of satisfying the requirements of new regulations on the fuel economy, automobile producers may need to make new models (combining higher fuel economy with other attractive attributes (such as safety and space) through technology improvement in engines and materials) available to attract more consumers.

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